

Offset Calculation for Registration-Free EM-based Liver Navigation

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Abstract:

Precise placement of ablation needles for the treatment of liver tumors remains difficult due to poor visibility of potential tumor targets in ultrasound imaging. Various groups have carried out extensive efforts to develop image-guidance and surgical navigation technology for the realm of oncologic liver surgery. Due to additional complexity and disruption in the clinical workflow, the barriers to introducing these systems on a larger clinical level remains high. In this work we present an initial evaluation towards a novel and simple method for accurate image-guided targeting of liver tumors based on EM-tracking and without requiring patient-to-image registration. The initial feasibility of the 3D offset calculation from fluoroscopy images is demonstrated.

Keywords: Liver Tumor Ablation, EM Tracking, Navigation, Fluoroscopy

1 Introduction

Among multiple locoregional treatment strategies used for early and intermediate stage hepatocellular carcinoma (HCC), local tumor ablation (by means of heat induced by Radiofrequency or Microwaves) represents one of the most directly tumor-targeted and locally destructive options. However precise placement of ablation needles remains difficult due to poor visibility of potential tumor targets in ultrasound imaging. In the past years, advanced image-guidance systems have been developed to allow navigation based on pre- and intra-operative image data (e.g. [1], [2] and [3]).

Despite the benefits of image-guidance approaches, the barriers to introducing this technology on a larger clinical level are high due to the complexity of these procedures and thus disruption of the intraoperative workflow. Thus in order to overcome many of the challenges associated with image guided interventions on the liver, we propose a novel approach for percutaneous targeting of intrahepatic lesions using EM-guided navigation and a transarterial angiographic approach for placement of an intrahepatic target reference. In this initial study, we specifically address the feasibility of calculating the 3D offset from two 2D fluoroscopy images, without registering the C-arm to the EM tracking system.

2 Materials and Methods

A window field generator (NDI Aurora, Northern Digital, Waterloo, Ontario, Canada) was mounted under the carbon fiber OR table in the angio suite. The window field generator was aligned parallel to the table using a water level to ensure that the coordinate system of the EM tracking was aligned with the C-arm (Artis Zee, Siemens, Berlin, Germany).

In order to evaluate the correspondence of the image measurements and the EM tracking, an initial analysis was performed with two EM tracked Chiba-tip needles placed in a foam block. The needle positions were measured by the EM tracking system and the xyz distances between them was calculated.

The C-arm was then aligned such that the two needles were in the isocenter and two images were acquired at 0° (anterior-posterior view) and 90° (lateral view). As the field generator was aligned with the OR table, the distances in the images could be measured and related to the xyz coordinates of the tracking.

In a second evaluation targeting of a tumor model using the proposed 3D offset calculation was assessed. A grape was placed on a 3D printed hollow model of the liver's vascular network to simulate a tumor inside the liver (Figure 1, left). A tracking sensor was placed inside one of the vessels and the entire phantom was placed into the isocenter of the C-arm. Again, 0° and 90° images were acquired and the xyz offset was calculated between the tip of the sensor and the center of the tumor (Figure 1, center). The position of the tumor (i.e. the sensor position plus the calculated offset) was then given as the target position into the navigation system (CAS-One IR, CAScination, Bern, Switzerland). An ablation needle

equipped with a glued-on EM sensor was used for targeting, relying on the directions indicated by the navigation. The final position of the ablation needle within the tumor model was assessed.

3 Results

Comparison of the distances between the image and EM tracking system resulted in a 3D difference of $\Delta x = 0.1$ mm, $\Delta y = 0.15$ mm and $\Delta z = 0.4$ mm (Euclidean distance of 0.44 mm). An error of 0.44 mm corresponds to approximately five pixels in the images used for the distance measurement.

One targeting attempt of the tumor model was performed using the targeting module of the navigation system. The center of the ablation antenna (transition between the black and the white part) was situated in the center of the tumor model, representing a successful targeting (Figure 1, right).

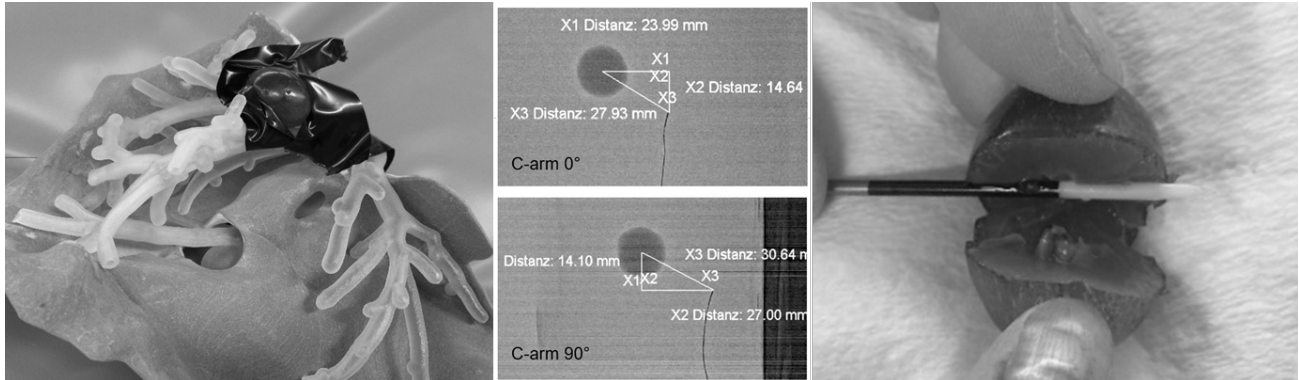


Figure 1: Left: setup, with sensor inside one vessel Center: fluoroscopic images with measured distances Right: post targeting image of the tumor model

4 Discussion & Conclusion

The small difference observed between image and EM tracking measurements suggests that calculating a 3D offset from two 2D fluoroscopic images is feasible. The successful targeting of the tumor model suggests a sufficient targeting accuracy when using the proposed calculation of the offset between the reference (i.e. an EM tracking sensor) and the actual target (i.e. the center of the tumor). The developed approach has the advantage of not requiring an explicit registration between image and tracking system coordinate frames, avoiding loss of targeting accuracy due to registration errors and reliance to preoperative imaging.

These preliminary results will allow the introduction of this 3D offset calculation into a novel method for percutaneous targeting and ablation of intrahepatic tumors, using a transarterially placed sensor as intrahepatic reference. Future work will focus on the evaluation of the proposed workflow assessing the achievable end-to-end targeting accuracy and efficacy. In-vivo experiments using an animal model will allow the evaluation of the proposed workflow in a more clinically realistic scenario.

This initial work represents a first evaluation towards a novel method for accurate image-guided targeting of liver tumors without requiring the patient to be registered to image data. The initial feasibility of the approach could be successfully demonstrated.

5 References

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